Diarrheal Illness Detected Through Syndromic Surveillance After a Massive Power Outage: New York City, August 2003

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Objectives. We investigated increases in diarrheal illness detected through syndromic surveillance after a power outage in New York City on August 14, 2003.

Methods. The New York City Department of Health and Mental Hygiene uses emergency department, pharmacy, and absentee data to conduct syndromic surveillance for diarrhea. We conducted a case–control investigation among patients presenting during August 16 to 18, 2003, to emergency departments that participated in syndromic surveillance. We compared risk factors for diarrheal illness ascertained through structured telephone interviews for case patients presenting with diarrheal symptoms and control patients selected from a stratified random sample of nondiarrheal patients.

Results. Increases in diarrhea were detected in all data streams. Of 758 patients selected for the investigation, 301 (40%) received the full interview. Among patients 13 years and older, consumption of meat (odds ratio [OR] = 2.7, 95% confidence interval [CI] = 1.2, 6.1) and seafood (OR = 4.8; 95% CI = 1.6, 14) between the power outage and symptom onset was associated with diarrheal illness.

Conclusions. Diarrhea may have resulted from consumption of meat or seafood that spoiled after the power outage. Syndromic surveillance enabled prompt detection and systematic investigation of citywide illness that would otherwise have gone undetected. (*Am J Public Health.* 2005;95:547–553. doi:10.2105/AJPH.2004.061358)

At 4:11 PM Eastern daylight savings time on August 14, 2003, an estimated 60 million people in 8 US states and 1 Canadian province (Ontario) experienced a sudden, massive power outage.[1] An estimated 9 million people in the New York City metropolitan area were affected. Electric power was unavailable in New York City from several hours to more than 2 days in some locations. The New York City Department of Health and Mental Hygiene (DOHMH) activated its emergency response system to address various public health concerns arising from the power outage.[2]

One concern was the potential for illness from the consumption of food from refrigerators that had been without power. Microbial pathogens can multiply in food to sufficient concentrations to cause gastrointestinal illness in as few as 2 hours at 41°F.[3,4]

DOHMH released 3 health alerts within 24 hours of the blackout urging the public to avoid eating foods prone to spoilage and immediately discard them. Alerts were sent to health providers recommending that they lower thresholds for collecting specimens for diagnostic testing in patients with diarrheal illness and that they advise parents of ill children to exclude children from child care and other group settings until the diarrhea resolved.

Syndromic surveillance systems are designed to detect increases and clustering of clinical syndromes representing natural or bioterrorism-related illnesses.[5,6] Four data sources used to monitor trends in syndromes in New York City (emergency department [ED] visits, pharmacy sales data from 2 sources, employee absenteeism) provide syndromic data indicative of diarrheal illness. A fifth data source (emergency medical service calls) does not contain data that indicate diarrheal syndromes. Syndromic data are transmitted and analyzed daily so aberrant patterns in illnesses of public health concern can be rapidly detected and promptly investigated.[7–9]

On August 15, 2003, despite the loss of power, the DOHMH received electronic files containing data for the previous day's ED visits from 9 of 41 hospitals through a wireless laptop computer operated from a gas-powered generator. DOHMH staff traveled to 29 EDs, where they reviewed medical records, tallied chief complaints by syndrome, and reported tallies to a central location. Tallies were entered manually and combined with the electronic data for routine daily analysis; concerning patterns were investigated immediately. On August 16, data were transmitted electronically from 13 hospitals. An additional 15 hospitals faxed paper chief complaint logs that were manually entered and combined with electronic data for routine analysis. On August 17, electronic data transmission was restored for 29 hospitals, and manual entry was discontinued.

During the 3 days after the power outage, increases in diarrheal illness were detected in each of the 4 syndromic data sources used to monitor diarrheal illness. This was the first time in 2 years of operations that an increase in a single syndrome was detected in every applicable data source. This increase was not reported through any other mechanism. In response, we conducted a case–control investigation to determine risk factors for diarrheal illness after the blackout.

METHODS

Syndromic Surveillance

The hospital ED system uses chief complaint data transmitted daily from each of 41 participating EDs. Patient ED visits are coded into syndromes (respiratory, fever/influenza, vomiting, diarrhea, rash, asthma, sepsis, cold) or "other" if the chief complaint does not fit into 1 of the 8 coded syndromes.[5] Citywide trends in the daily ratios of visits for each specific syndrome to other visits are displayed graphically and evaluated with the temporal scan statistic.[10,11]

The over-the-counter pharmacy system uses medication sales data transmitted daily by a major pharmacy chain.[12] Sales of generic and brand name loperamide (Imodium) and pink bismuth are used to monitor trends in diarrheal illness. A cyclical linear regression model[13,14] is used to detect aberrations in the number of antidiarrheal sales, adjusting for season and day of week. Adjusted sales that exceed the 95% confidence interval of the model are considered aberrant.

The National Retail Data Monitor system uses sales of electrolyte formulations (not collected by the over-the-counter system) compiled from New York City outlets of several national pharmacy chains to track diarrheal illness among young children.[15] Daily sales are adjusted for day of week with linear regression, and the CuSum method[16] is used to determine whether adjusted sales exceed the 14-day baseline mean plus 3 standard deviations.

The worker absenteeism system monitors data from a large city agency (15 000 employees) that requires workers to report the reason for their absence.[17] Trends in the daily count of absences because of a gastrointestinal syndrome (diarrhea or vomiting) are assessed with the CuSum method[16] to determine whether daily counts exceed the 7-day baseline mean by more than 3 standard deviations.

Case–Control Investigation

Patients were eligible for the investigation if, during August 16 to 18, they presented with diarrheal syndrome or "other" syndrome to 1 of 20 New York City EDs that (1) participated in syndromic surveillance, (2) were able to provide patient contact information, and (3) saw more than 4 patients with diarrheal syndrome during the 3-day period.

All 213 eligible patients who presented with diarrheal syndrome were initially designated case patients. A random sample of 545 patients (2.5 times the number of cases) was selected from the 13 394 eligible patients with "other" syndrome, frequency matched to diarrheal syndrome patients by age group (<13, 13 to 39, 40 to 64, and ≥65 years); these patients were initially designated control patients. Final case status was determined after interviews with patients.

Hospitals provided the names and telephone numbers of selected patients to the DOHMH in compliance with the New York State Sanitary Code[18] that requires public health officials to investigate disease outbreaks; and the public health exemption to the Health Insurance Portability and Accountability Act.[19] Trained DOHMH staff telephoned patients between 9 AM and 9 PM, during August 21 to 28, 2003, and administered structured questionnaires to patients aged 16 years and older and to adult guardians of younger patients. When staff members were unable to reach selected patients with the numbers provided, they searched local and Internet sources for correct numbers and made up to 5 additional attempts to reach each patient. Questionnaires were printed and administered in English. If a patient's first language was not English and bilingual interviewers were available, questionnaires were administered in the patient's native language (including Russian, Spanish, French, and Cantonese) instead of in English.

All patients were asked about symptoms and date of onset. Patients who had diarrhea or "other" symptom onset after the power outage began were also asked which foods they consumed between the power outage and symptom onset; when (time and date) each item was consumed; whether each food item was prepared at home, purchased precooked from a store, or eaten at a restaurant; which food items were discarded after the power outage; and whether they heard prevention messages about food safety. Administration of the full questionnaire took 15 to 20 minutes. Regardless of syndrome classification, patients who reported that they had diarrhea after the power failure were defined as case patients, and those who denied having diarrhea were defined as control patients.

Data were entered by trained data entry staff and analyzed with SAS software (SAS Institute Inc, Cary, NC). We compared differences in demographics, symptoms, and exposures among case patients and control patients and determined whether differences were statistically significant with χ^2, Fisher exact test, Student *t* test, Wilcoxon rank sum test, and test of proportions (test specified unless a χ^2 test was used). Data were explored for confounding and interaction with multiple variable regression modeling.

A majority (56%) of study participants were younger than 13 years, and the distribution of ages within this stratum was skewed toward young children (12% younger than 1 year). Hypothesizing that infants and young children would eat different foods and present with a different constellation of diarrheal symptoms than teenagers and adults, we stratified analyses into children younger than 13 years and teenagers and adults aged 13 years or older (the latter included persons aged 13 to 39, 40 to 64, and ≥65 years).

RESULTS

Syndromic Surveillance

On Sunday, August 16, 2003, ED data received from 29 of 41 participating EDs indicated 70% more patient visits for diarrheal syndrome than expected (117 observed vs 63 expected, $P<.01$; Figure 1). The following day, increases were observed in antidiarrheal medication sales (over-the-counter sales=905 vs model-predicted 95% [CI]=[249, 563]; Figure 2) and electrolyte sales (National Retail Data Monitor; adjusted sales=276 vs baseline=194 ±25) and in the number and proportion of worker absences because of gastrointestinal illness (worker absenteeism=74 [29%] vs baseline=44 ±4 [18%], figure not shown).

Case–Control Investigation

Of 29 EDs reporting syndromic surveillance data on August 16 to 18, 26 EDs reported at least 5 patients with the diarrheal syndrome, and 20 of these EDs provided patients' medical record numbers. Of 213 case patients and 545 control patients selected, 137 (64%) case patients and 310 (57%) control patients were reached. Of those reached, 133 (97%) case patients and 283 (91%) control patients agreed to participate, and of those who agreed, 99 case patients (74%) and 202 (71%) control patients had symptom onset after the power outage and were administered the full questionnaire (Figure 3). Case and control patients who were reached were younger than those not reached (median age=11 vs 31 years, $P<.01$), but there

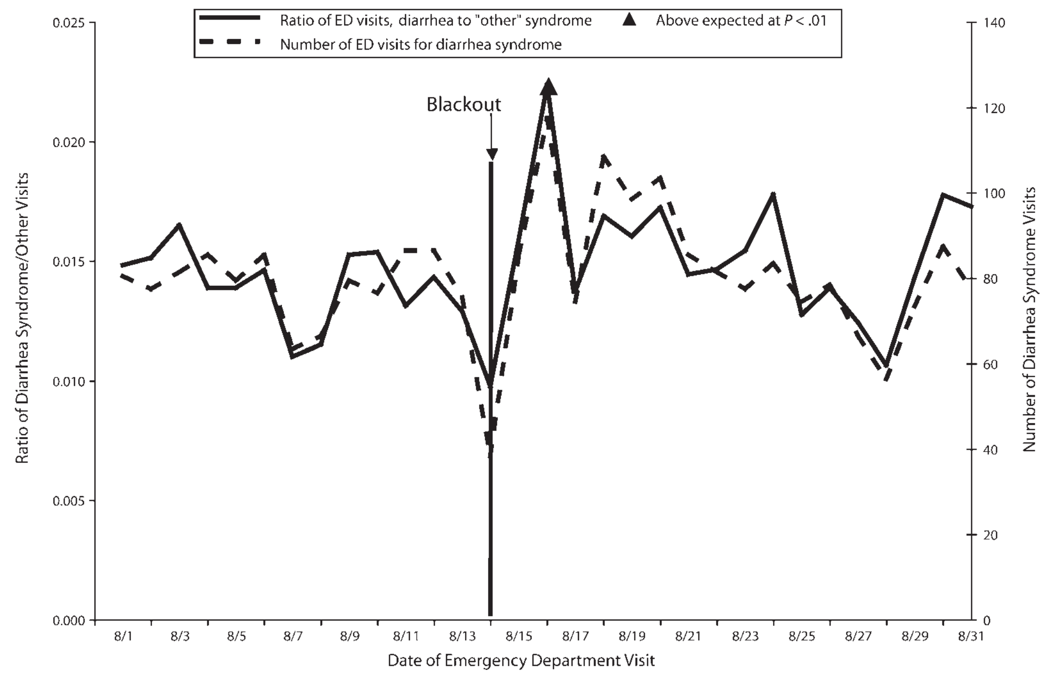
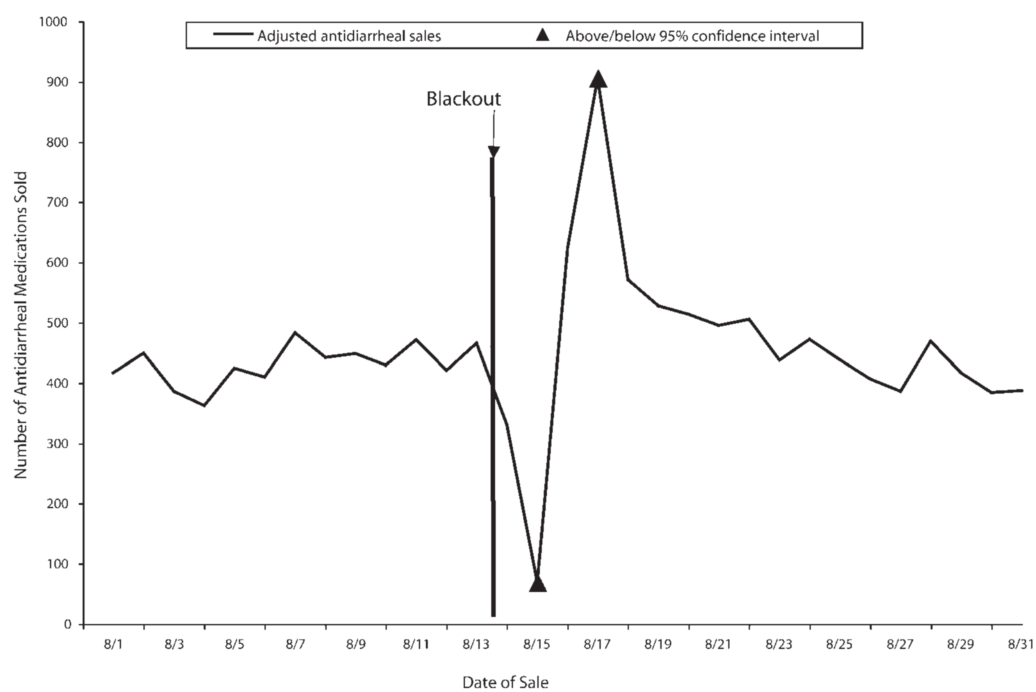


FIGURE 1—Ratio of emergency department (ED) visits for diarrheal illness to other visits and total number of diarrhea visits: New York City, August 2003.



Note. Data are adjusted for day of week, holiday, and air temperature.

FIGURE 2—Number of over-the-counter pharmacy sales for antidiarrheal medications: New York City, August 2003.

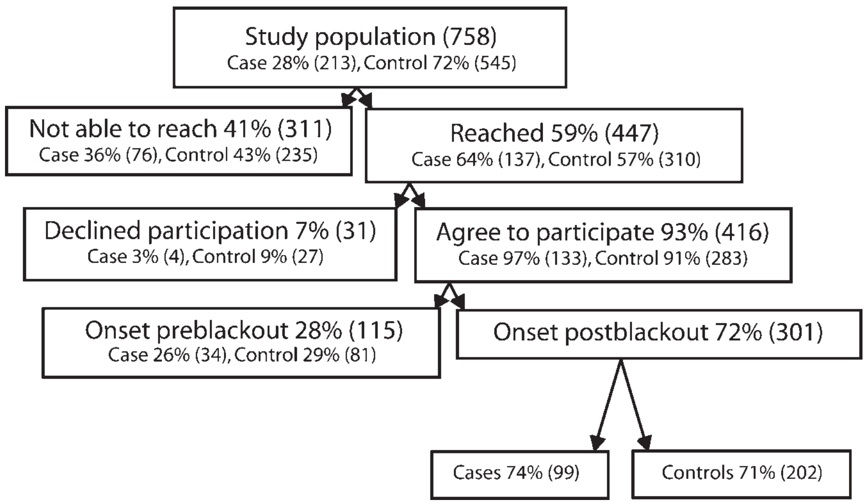


FIGURE 3—Participation in investigation on the basis of syndrome-based case definition: New York City, August 2003.

was no difference in median age between those who agreed and those who declined to participate. The gender distribution did not differ on the basis of whether the patients were reached or agreed to participate.

Of 301 case and control patients interviewed, 149 (50%) were female. The median age was 11 years, but age varied considerably (SD=26.0). Of 99 potential case patients interviewed, 11 (11%) denied having diarrhea and were reclassified as control patients, and 3 (3%) declined to report whether they had had diarrhea and were excluded from further analyses. Of the 202 potential control patients interviewed, 31 (16%) reported having had diarrhea and were reclassified as case patients, and 11 (5%) declined to report whether they had had diarrhea and were excluded from further analyses. Reclassified case patients did not differ from reclassified control patients in gender or age distribution.

Two thirds (67%) of case and control patients reported having heard messages suggesting that they avoid consuming foods prone to spoiling when not refrigerated. Patients received messages from television (54%), the radio (43%), by word of mouth (15%), in print (6%), and through other mechanisms (10%), including "common sense." Case status was not associated with whether or how patients received prevention messages.

Power was disrupted in participating patients' homes for an average of 24 hours (for both case and control patient groups, range=1.8 to 97.8 hours; SD=12.3 hours). Case patients had symptoms beginning an average of 50 hours (range=7.8 to 101 hours; SD=25.0 hours) after the power outage began, lasting an average of 98 hours (range=<1 to 254 hours; SD=61.5 hours). Besides diarrhea, the most common symptoms reported by case patients included cramps (68%), loss of appetite (66%), nausea (54%), vomiting (49%), and headache (48%). Almost half (46%) of case patients reported fever, 11% reported bloody diarrhea, and 22% were admitted to the hospital. Approximately 54% of patients reported diarrhea alone, 20% reported diarrhea with fever, and 26% reported diarrhea and vomiting.

We found no differences in the percentage of case and control patients reporting common nonfoodborne diarrheal risk factors (Table 1). However, between the power outage and symptom onset, 68% of participating patients consumed at least 1 food item considered at high risk for contamination (i.e., seafood, poultry, dairy food/beverages, deli meat/other meats). The proportion of case and control patients consuming these and other foods examined differed substantially by age.

When patients were stratified into 2 age groups, 58 (50%) case patients and 100 (58%) control patients were children (aged younger than 13 years). Among children, case patients were slightly younger than control patients (median=2.0 vs 3.4 years, Wilcoxon P=.04), but the groups did not differ by gender (40% vs 46% female, P=.44). No discernable differences were detected in the proportion of case and control patients younger than 13 years reporting any of the traditional diarrheal risk factors described previously, or reporting having consumed or discarded bread, vegetables/fruit, poultry, seafood, dairy food/beverages, deli meat, or other meats after the power outage (Table 1). Similarly, no associations were found when data were modeled while taking age into consideration (data not shown).

Among teenaged and adult patients (aged 13 years or older), 58 (45%) were case patients and 71 (55%) were control patients. The proportion of females (62% vs 59%; P=.70) and the median age (45.8 vs 48.5 years, Wilcoxon P=.44) did not differ by case status. Unlike the proportion of children, however, the proportion of teenaged and adult case patients consuming high-risk foods was higher than that of control patients for nearly all foods listed (Table 1). The majority of these differences were not statistically significant. However, the odds of consuming seafood (27% vs 7%; OR=4.8; 95% CI=1.6, 14.1) and other meats (36% vs 17%; OR=2.7; 95% CI=1.2, 6.1) were higher in teenaged and adult case patients than in control patients (Table 1). Of adult and teenaged patients who ate seafood and other meats, case patients consumed seafood a median of 5.8 hours, and meat a median of 21.5 hours before symptom onset. The source of specific foods (i.e., whether they were prepared at home, purchased precooked from a store, or consumed in a restaurant) did not differ by case status (data not shown).

DISCUSSION

This investigation illustrates the capacity of syndromic surveillance to detect outbreaks that traditional surveillance might

TABLE 1—Diarrhea Risk Behaviors of Case and Control Patients by Age Strata: New York City, August 2003

	Children[a]			Adults and Teenagers[b]		
	Cases (n = 58), %	Controls (n = 100), %	Odds Ratio (95% CI)	Cases (n = 58), %	Controls (n = 71), %	Odds Ratio (95% CI)
Nonfoodborne diarrheal risk factors						
Lost access to tap water	26	32	0.8 (0.4, 1.6)	23	20	1.2 (0.5, 2.8)
Swimming	7	5	1.3 (0.4, 5.4)	0	0	...
Travel	9	6	1.4 (0.4, 4.8)	7	12	0.6 (0.2, 2.0)
Exposure to sick person	2	2	0.8 (0.1, 9.4)	4	3	1.1 (0.2, 8.2)
Foods consumed						
Seafood	5	3	1.7 (0.3, 8.8)	27	7	4.8 (1.6, 14.1)
Deli meats	14	20	0.7 (0.3, 1.6)	25	19	1.5 (0.6, 3.4)
Poultry	26	34	0.7 (0.3, 1.4)	43	39	1.2 (0.6, 2.4)
Other meats	26	25	1.1 (0.5, 2.2)	36	17	2.7 (1.2, 6.1)
Dairy foods/beverages	52	52	1.0 (0.5, 1.9)	46	36	1.6 (0.8, 3.2)
Vegetables/fruit	28	37	0.7 (0.3, 1.3)	43	43	1.0 (0.5, 2.0)
Bread	31	41	0.6 (0.3, 1.3)	58	52	1.3 (0.7, 2.7)
Foods discarded						
Seafood	27	30	0.8 (0.4, 1.9)	41	24	2.2 (0.9, 5.3)
Deli meats	51	51	1.0 (0.5, 2.1)	51	41	1.5 (0.7, 3.3)
Poultry	69	70	1.0 (0.5, 2.1)	59	51	1.4 (0.6, 3.1)
Other meats	78	76	1.1 (0.5, 2.5)	71	61	1.6 (0.7, 3.7)
Dairy foods/beverages	77	71	1.4 (0.6, 3.1)	78	78	1.0 (0.4, 2.6)
Vegetables/fruit	53	66	0.6 (0.3, 1.2)	61	57	1.2 (0.5, 2.7)
Bread	41	38	1.1 (0.5, 2.3)	43	31	1.6 (0.7, 3.7)

Note. CI = confidence interval.
[a]Age < 13 years.
[b]Age ≥ 13 years.

miss. Syndromic surveillance can also facilitate rapid investigation and implementation of containment and control measures. Investigation data indicated that among adults, the diarrheal illness detected through syndromic surveillance was associated with consuming meat or seafood.

Local health departments usually identify outbreaks from passive laboratory- and provider-based surveillance data and clinicians' reports of unusual patterns. Although routine analysis of reportable disease data can identify changing patterns in the distribution of notifiable illnesses, nonnotifiable and emerging infections (e.g., severe acute respiratory syndrome), or outbreaks because of infectious diseases for which diagnostic tests are rarely requested (e.g., norovirus) cannot be identified this way.

Clinicians report suspected outbreaks more often when large or concentrated clusters occur, especially when the patients involved present with severe or uncommon symptoms (e.g., West Nile virus[20]) or have shared, known exposures (e.g., prairie dogs: 2003 monkeypox outbreak[21]; letters: 2001 anthrax release[22]). However, clinicians are less likely to notice and report disease clusters that are widely disseminated, especially if the illness is mild or common (e.g., diarrheal, influenza-like illness). Syndromic surveillance allows us to monitor data for citywide increases or clustering in these nonspecific syndromes that might otherwise go undetected.

In the 3 days after the blackout, an average of 3 (range 2 to 7) more patients presented with diarrheal complaints than expected in 7 of 21 EDs, resulting in a statistically significant citywide increase in diarrhea. These modest increases were not reported by traditional physician or hospital reporting sources. The majority of other hospitals experienced 1 to 2 excess diarrhea cases. Although syndromic surveillance has been less effective for detecting very small (e.g., anthrax, 2001[22]) or widely scattered outbreaks, we used data from multiple data streams to detect a moderate but widespread increase in diarrhea citywide after the August 14, 2003, power outage.

The increase in diarrheal illness detected through syndromic surveillance was not detected by other surveillance systems. Retrospective analysis of traditional surveillance data revealed no increase in salmonellosis, listeriosis, shigellosis, yersiniosis, or campylobacteriosis in the 4 weeks following the power outage. Similarly, we did not observe an increase in the number of fecal specimens submitted for bacterial culture and sensitivity, or ovum and parasite testing to 3 sentinel surveillance laboratories[23] in the week following the power outage, with the exception of 1 day (August 19), which was attributed to backlogged specimens. However, surveillance data for the majority of enteric pathogens is limited; the majority of patients with diarrheal illness do not seek medical care, and reporting is notoriously incomplete.[24]

Although a causal link between the power outage and illness from consumption of spoiled food is plausible given previous outbreaks[25–27] and temperature studies,[3] in the absence of stool or food cultures, we cannot draw definitive causal inferences from this investigation.

DOHMH disseminated messages about the prevention of foodborne illness through public and provider health advisories before increases were observed in syndromic surveillance data. The agency continued distributing these advisories after the increase was detected. More than two thirds of patients interviewed reported hearing these messages after the blackout. The majority of patients reported hearing messages on television or on the radio. Although we did not ask whether they heard public health messages before or after food was consumed or power was restored, patients who heard these messages had the same odds of having diarrhea and of eating or discarding foods as those who did not hear the messages.

Adult patients ate a wider variety of foods than did children, most likely reflecting true differences in consumption, but also potentially reflecting inaccurate reporting by guardians of their children's food consumption. Details about foods consumed after the power outage might have been difficult to recall. If case patients remembered foods consumed more accurately than control patients because they were attuned to gastrointestinal issues, estimates of associations for perishable and nonperishable food items would both be artificially inflated. An across-the-board inflation in estimates was not evident in the data.

We identified patients for this investigation with ED syndromic surveillance data. Preexisting relationships between DOHMH and ED staff and knowledge of the DOHMH's mandate to investigate outbreaks allowed us to obtain patient-level information expediently and conduct interviews rapidly after we learned about the possible outbreak. To protect our ED partners from unnecessary burden, we restricted this investigation (and requests for information) to hospitals that saw more than 4 diarrhea patients during the investigation period. Without the system and these relationships, we would not have detected nor been as easily able to investigate the increase.

We identified case patients and control patients for this investigation on the basis of their ED chief complaint–coded syndromes and then reclassified them after they indicated whether they reported having had diarrhea on ED presentation. Using this protocol, we reclassified as control patients 11 patients whose chief complaint indicated diarrheal syndrome but who did not report diarrhea, and reclassified as case patients 31 patients whose chief complaint indicated "other" syndrome but who reported diarrhea. We could have analyzed data according to an intention-to-treat methodology[28] by basing case patient status on original case designation. When we estimated the effect of reclassification by performing post hoc analyses to compare associations derived from the syndrome-based case definitions to those we derived from reclassified case definitions, we obtained similar results, suggesting that misclassification was likely nondifferential.

If ED-based control patients did not have the same opportunity to consume poorly refrigerated food after the blackout as case patients, using them as controls would artificially inflate associations and would be an important limitation to this investigation.

We maintained syndromic surveillance during the power outage by telephoning EDs, relocating to an office with a generator, and receiving and entering data from faxed ED logs. Even with this effort, our analyses were limited because we were missing data from 12 (of 41) syndromic surveillance EDs.

The sharp decline and subsequent rise in over-the-counter sales (Figure 2) during and after the blackout can likely be attributed partly to store closures/reopenings. In the context of the other indications of citywide diarrhea, we assumed that despite this apparent artifact, true increases in diarrhea could also have been occurring. Post hoc analyses of the proportion of antidiarrheal to total sales indicated that antidiarrheal sales increased above overall volume, supporting this assumption. On August 17, we had seemingly consistent and credible evidence of a citywide increase in a largely preventable condition. In lieu of waiting for complete data with irrefutable trends, we decided to notify the public and provide recommendations for prevention.

The ability of syndromic surveillance to enhance disease surveillance is limited by at least 3 main factors. First, a key feature of syndromic surveillance is that data are available quickly after medical encounters, and consequently the specificity and sensitivity of these data are relatively low (e.g., sensitivity of ED patient chief complaints=44%).[29] Coding methods used to categorize data into syndromes inevitably involve somewhat arbitrary choices, further compromising the validity of categorized data. Second, disease occurrence among patients presenting to EDs participating in syndromic surveillance might not be comparable to that among the general population. Third, maintaining syndromic surveillance systems requires technical support and personnel (New York City DOHMH's system costs approximately $150 000/year to maintain).[17] Funding used for syndromic surveillance activities might otherwise support building and maintaining traditional public health infrastructure. Despite these limitations and ongoing debate over the usefulness of syndromic surveillance, since 2001, federal, state, and local public health officials have made developing and implementing syndromic surveillance systems a high priority.[8]

Syndromic surveillance was useful for detecting an increase in diarrheal illness in New York City after the 2003 power outage. In fact, we had no other indication of citywide illness. Our system does not regularly detect localized foodborne outbreaks reported by physicians or patients and did not detect the small 2001 outbreak of cutaneous anthrax infections associated with contaminated mail. However, New York City's system has facilitated the early detection of citywide seasonal increases in influenza[6,9] and gastrointestinal illness attributable to norovirus and rotavirus,[12] allowing us to inform physicians and the general public at the start of each annual outbreak and remind them of prevention strategies.

Syndromic surveillance systems can improve our capacity to detect and quickly investigate widespread increases in the incidence of emerging infections. When used in conjunction with traditional surveillance efforts, these systems can improve public health preparedness. ■

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Contributors

M.A. Marx determined investigation methods; oversaw data collection; cleaned, analyzed, and oversaw analysis of data; and wrote the article. C.V. Rodriguez designed and wrote the data collection instrument, interviewed patients, and analyzed data. J. Greenko coordinated data collection, interviewed patients, and contributed to the analysis of data. D. Das designed the database and assisted with extracting existing records from the existing surveillance system. R. Heffernan oversaw data

extraction and analysis and assisted with describing the components of our syndromic surveillance system. A.M. Karpati contributed to the conception and design of the investigation and edited drafts of the article. F. Mostashari assisted with the design and conduct of the investigation and the writing of the article. S. Balter assisted in the design of the investigation, oversaw data collection, and contributed to the writing of the article. M. Layton contributed to the conception and design of the investigation and assisted in editing the article. D. Weiss oversaw the project, including design of the study, collection of the data, and the data analysis and edited several versions of the article.

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